

Visualizing Changing Landscapes: Disappearance of the Scioto Lobe of the Laurentide Ice Sheet, Ohio

A Field Guide

Presented by:

Daniel Leavell

Mike Angle

Bryan Mark

Ian Howat

**INTERNATIONAL GLACIOLOGICAL SOCIETY
INTERNATIONAL SYMPOSIUM ON
EARTH'S DISAPPEARING ICE:
DRIVERS, RESPONSES AND IMPACTS**



IGS

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Visualizing Changing Landscapes: Disappearance of the Scioto Lobe of the Laurentide Ice Sheet, Ohio

A field guide to accompany the symposium of the International Glaciological Society:

Earth's Disappearing Ice: Drivers, Responses and Impacts

Presented by The Ohio State University and the Ohio Geological Survey

August 18, 2010

Prepared by:

Daniel Leavell, OSU

Michael Angle, OGS

Bryan Mark, OSU

Ian Howat, OSU

Introduction

Landforms associated with the Scioto Lobe of the Laurentide Ice Sheet (LIS) in east central Ohio during the Last Glacial Maximum (LGM) reveal the processes, materials and environments of the glacier system. We reconstruct the paleogeography and glacial history to provide a model of changes at and near the ice margin on this glaciated section of the Appalachian Plateaus Province at 40°N. In eastern Licking County, kames, terraces, moraines, ice-marginal lake deposits and reversed drainage systems record the impact of the glacier at and beyond the terminus. Field stops will highlight glacial, glacialfluvial, and glaciallacustrine landforms and related materials (e.g. till, outwash gravel, lake sediments and peat deposits) as we seek to improve our understanding and visualization of the glacier system.

As the ice disappeared, landforms continued to evolve and lake basins and kettles accumulated the record of a changing biosphere, one in which northern species of trees gave way to hardwoods and some Ice Age animals disappeared. Research on materials from the Burning Tree mastodon site (1989) in Licking County has provided new insight to the paleoenvironment, the mastodon diet, viability of bacteria, and our understanding of human occupation of Ohio 13,000 years ago. After viewing a timeline of ancient cultures at the Great Circle Earthworks Museum in Heath, participants can explore the adjacent Newark Earthworks. Built by the prehistoric Hopewell about 2000 years ago, the earthworks had ceremonial, social and astronomical functions and are the largest set of geometric earthen enclosures in the world. The Newark earthworks are evidence of the importance of the Newark area during the height of the Mound Builders culture in this area and are indicative of the large population and

advanced culture which developed on these fertile ice-margin areas. The geometric mounds were a ceremonial ground as well as an accurate lunar calendar which was likely used for agricultural purposes.

Glacial Geologic Setting of Ohio

Central Ohio, Columbus and much of Licking County were repeatedly covered by ice during the Pleistocene. Evidence exists in Ohio for three major advances, beginning with the Pre-Illinoian Stage more than 300 ka BP. The only evidence for this advance preserved in Ohio is a small area in the southwest at Cincinnati. Evidence for the Illinoian Stage (ca 70 ka BP) is well preserved in Licking County, as we will see on this field trip. Wisconsinan deposits as young as 10 ka BP are well displayed at the surface over much of Ohio and the relationship of the deposits of the Illinoian and Wisconsinan Stages are nowhere better seen than in Licking County. Please see the appendices of this volume for a series of geologic maps produced by the Ohio Geological Survey (OGS) which illustrate the erosional and depositional history of the ice ages in Ohio.

During the last Glacial Maximum (LGM) (18-24 ka BP) Columbus was covered by the Scioto Lobe of the LIS, which reached the western edge of the Appalachian Plateau to the east. There it disrupted drainage, formed ice-marginal lakes, end moraines and ice-contact topography (kames and outwash terrace deposits). The objective of this trip is to understand the development of the present landscape and the importance of the advance and retreat of the LGM. We will also consider the relationship of the early man and the animals near the ice margin and how the Mound Builders (ancestors of Native Americans in this region) utilized the abundant natural resources of the area. Today, the resources left behind by the glaciers provide important water and rock resources and are responsible for the fertile agricultural land that supports a robust agrarian economy throughout central Ohio.

Pre-glacial Drainage and Post -glacial Rearrangement

Prior to the onset of Pleistocene glaciation, a major river system drained most of Ohio, West Virginia and the central Appalachian Plateau (Figure 1). This river, the Teays, entered Ohio at its southern margin and flowed north and west, exiting the state in Mercer County and continuing westward to join the Mississippi River. Advance of the earliest stage of ice blocked the Teays River and many of its tributaries including the Newark River, and caused a major reorientation of the drainage of the Midwest. A large lake was formed in southern Ohio, West Virginia and Kentucky which is called Lake Tight. This lake covered 7000 square miles and was at least 900 feet deep (Hansen, 1995). When this lake overflowed a new system of drainage, the Ohio River and its tributaries was created. Subsequent advances of ice (both Illinoian and Wisconsinan) further rearranged the drainage of regions large and small, with a net effect in Licking County and the Newark area of reversing the drainage and ultimately creating the Licking River network which today is tributary to the Muskingum River.

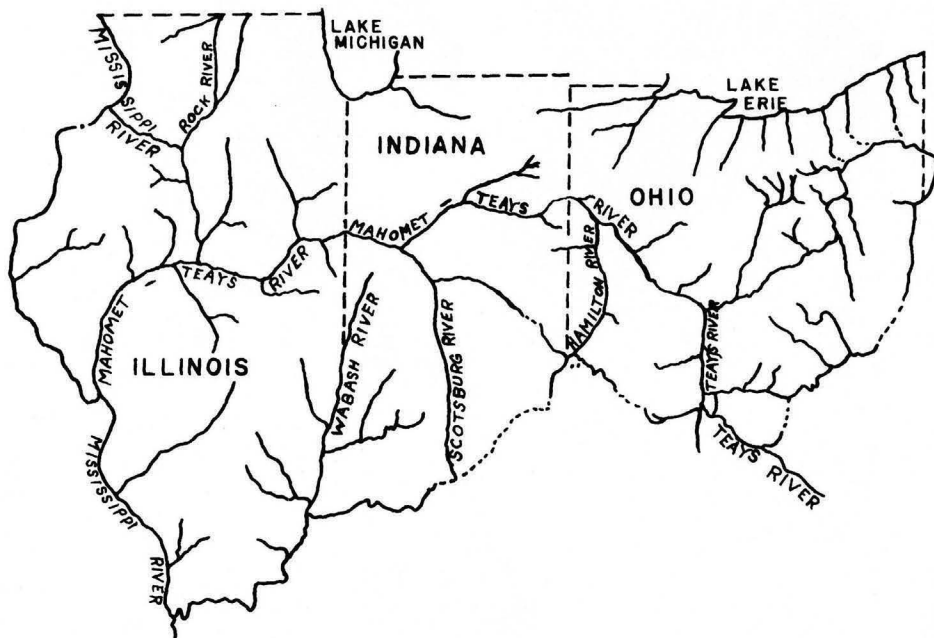


FIGURE 4. Nebraskan drainage.

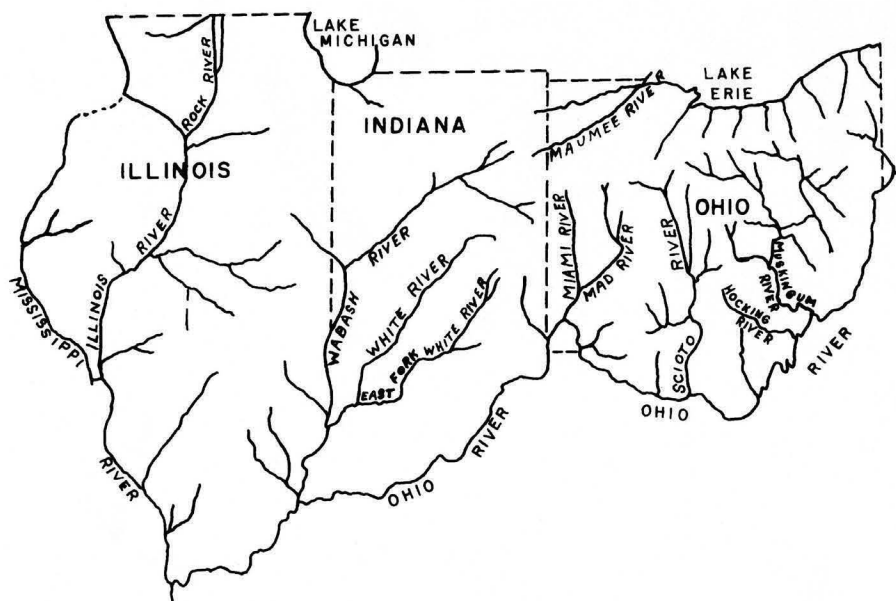


FIGURE 5. Kansan drainage.

Figure 1. Drainage patterns of the Midwest before and after the Pre-Illinoian glacier. Taken from Coffey, 1961.

Field Trip to Central Licking County

The IGS field trip will begin at Ohio State in Columbus, **Stop A** on the route map in Appendix A. Buses will proceed directly west past the airport and up onto the till plains of the western edge of the Appalachian Plateau to Granville, where lunch, map orientation and discussions will be held. A map of the field trip route with stops is included as the first plate of the Appendices. A turn by turn guide is also included with Appendix A.

Stop B: Wildwood Park, Granville

Lunch and lecture. After the ride from Ohio State, this stop will allow us to stretch our legs, enjoy a box lunch and get acquainted with the geology of Licking County. The park is located above the Raccoon Creek buried-valley aquifer and is adjacent to the village well-field. The well-field is developed in stratified outwash which has filled the pre-existing eroded bedrock valley to a depth of at least 200 ft at its center. The ground water table near the center of the valley is about 20 ft below the surface, and the large production wells are screened at about 100 ft. Average production of the well-field is 850,000 gallons per day.

We will follow Raccoon Creek upstream to Stop C, along the stream and between kames and kame terraces. Raccoon Creek, a major tributary to the Licking River, occupies a flood plain within the wider buried-valley. Terraces along Raccoon Valley Rd. are well developed and represent deposition by the much larger meltwater streams which flowed through the valley as the ice receded from the area.

Stop C: Brookside Materials, Alexandria

Brookside Materials is a small sand and gravel works which also sells locally produced and amended topsoil, and operates a large yard-waste recycling center and mulch production facility. Alexandria Village sits on another broad kame terrace. At the entrance to Brookside, a new borrow pit has been excavated to obtain sand and gravel for sale. Exposures in the walls above the pond show a complex history of stratified deposition, erosion and local collapse of the terrace materials. Excavations from the pond show good examples of Wisconsinan till.

We will spend 20-30 minutes examining the variety of materials and structures exposed in the excavation walls. Several trip leaders will be available for discussion and to answer questions.

Please be very careful above the pond and do not get too close to the highwall.

Upon departure from Brookside Materials we will travel across a series of till covered plains, ridges and modern stream valleys to reach the North Fork Licking River. This larger stream flows southerly along what is today the eastern margin of the Scioto Lobe of the LIS. The eastern side of the valley is covered by Illinoian Stage deposits which are, for the most part, deeply weathered. The valley is underlain by thick deposits of stratified outwash of Wisconsinan age that is underlain at depth by a significant thickness of Illinoian till deposits. Today these gravels are an important source of sand and gravel resources and a significant groundwater aquifer.

Stop D: Smoot Lake Kame and Kettle, St. Louisville

Smoot Lake and the adjacent Torren's Bog provide classic examples of kame and kettle topography associated with the rapid melting of the final Wisconsinan ice-advance. Appendix 2 shows a map of these features derived from Forsyth, 1965. These features are located along Lake Fork, a relatively short, high gradient, deeply incised tributary along the western side of the North Fork of the Licking River. These features occur along the tributary near its confluence with the trunk stream. During the late Wisconsinan, a thick accumulation of ice occupied both the upland west of the North Fork Licking River Valley and the North Fork Licking River Valley itself. The southerly flowing streams provided a great conduit for meltwater and associated coarse valley train deposits were deposited along the North Fork of the Licking River. Along the margins of the valley, especially near the confluence of ice-choked tributaries, slower wastage of the ice resulted in some spectacular kame features interspersed with low kettles. Smoot Lake and Torren's Bog represent two great examples of ice-block melting that resulted in kettles and depressions which are surrounded by coarse, relatively steep-sided kames. Together, these features create a unique, scenic landscape that affects local land uses including agriculture, groundwater supplies, and aggregate resources.

Stop E: Dog Hollow and Peat Moss Rd., St. Louisville

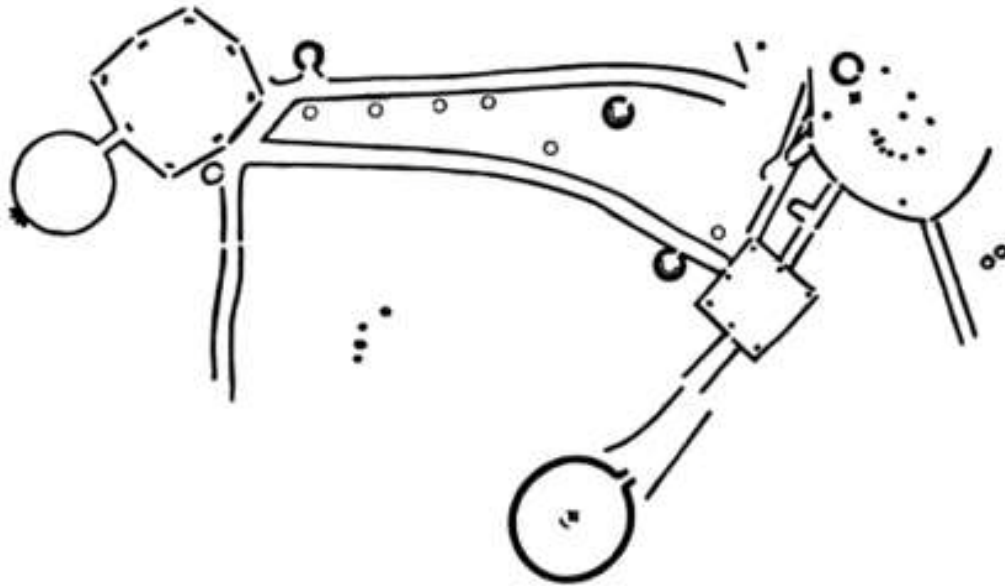
Peat Moss Road is built upon a former tributary valley along the eastern flank of the North Fork Licking River Valley (see Appendix 2 for related glacial map). This steep sided, high gradient, formerly southerly flowing tributary was blocked as the thick ice that accumulated in the North Fork Licking River pushed eastward into the tributary valleys, blocking them. Within Dog Hollow the ice was actually flowing northward, uphill toward Peat Moss Rd. Deposits include both thick till as well as some ice contact kames. Forsyth reported some evidence of Illinoian age kames in this area which would suggest similar events occurred during previous glaciations. These deposits served to dam the former south-flowing stream causing ponding which allowed a slow accumulation of fine-grained and organic materials. Eventually, as the ice melted and new drainage systems became established, the stream reversed direction and began flowing northeastward as it was captured by the headwaters of Rocky Creek. As the pond waters receded, the depression filled with rich organic materials creating thick peat and muck deposits.

Stop F: Great Circle Earthworks State Memorial, Newark

About half the group can visit the museum while the others tour the Great Circle. All will have an opportunity to visit both the mound and the museum.

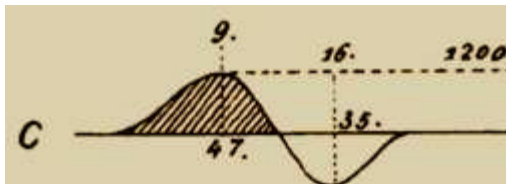
Newark's earthworks were built by the Hopewell people about 2000 years ago (see detailed map in Appendix 7). They are considered to be the largest geometric earthwork enclosures in the world and are considered to be one of 70 wonders of the ancient world. The major elements which remain today are the great circle and about 2 miles to the west is a large circle

with an interconnected octagonal mound. The octagon (which we will not visit) is now preserved as a private golf course and country club. It was originally built as a lunar observatory and its geometry aligns with the 18-year cycle of migration of the moonrise. The great circle looks a bit like a fortress, but both mounds and several other interconnected structures were probably great ceremonial and social spaces. In the museum you can learn much about these earthworks and the people who built them, as well as the broader Hopewell culture in the upper Mississippi Valley drainage basin.



The Great Circle

The Great Circle has the highest of the embankments at Newark. Based on survey, in this section of the "Newark Works," Whittlesey, Squier, and Davis (1837-47) reported nine feet high and 45 feet wide at their base embankments surrounding the seven feet deep and 35 feet wide ditch. They reported the entrance is emphasized with 16 foot high embankments above a 13 foot ditch.



<http://www.jqjacobs.net/archaeo/newark.html>

Stop G: Burning Tree Golf Course, Ridgely Tract Rd.

This stop is a quick view of the locale of the Burning Tree mastodon, discovered during excavations for a new pond at the golf course. The mastodon, one of the most complete specimens ever discovered in Ohio, was unearthed in 1989 from a former kettle or peat bog located on the margin of the local moraine which underlies most of Dawes Arboretum. The animal had been killed and butchered by hunters about 13,500 years ago. Bones were found in three bundles which had been weighted down and stored in the cool bog water for preservation. However, the hunters never came back for their meat and the resultant skeleton was nearly complete when reassembled.

Preserved with the skeleton were portions of the intestines of the mastodon which contained residual grasses and reeds that the animal had been eating before it was killed. Remarkably, the intestine also contained living bacteria which microbiologists were able to revive and study. These bacteria had existed for more than 13,000 years. The complete skeleton was sold to the Kanagawa Museum in Yokohama, Japan for more than \$600,000 in 1993.



Stop H: Dawes Arboretum

Dinner and a social gathering will be held at Dawes Arboretum in Jacksontown on SR 13 south of Newark. The arboretum was founded by Beman and Bertie Dawes in 1929. Beman Dawes was a prominent businessman locally and founded a petroleum refinery (Pure Oil) in Newark. His older brother was vice president of the United States under Calvin Coolidge.

There are more than 15,000 living plants on the arboretum's grounds, and most are hardy in central Ohio. Of these plants, 4,500 are unique names (taxa). Records kept for each plant include specific location, scientific and common names, origin and age. Soils of the arboretum are developed on ground moraines and recessional moraines deposited very close to the southeastern edge of the Wisconsin Scioto lobe. A sketch map of the surficial geology of the arboretum was mapped by Jane Forsythe (1980) and is included below. Forsyth also was the author of the Licking County glacial geology map published by the ODNR (1966). This mapping was part of her dissertation at The Ohio State University.

We hope that you have enjoyed this excursion into the glaciated western margin of the Appalachian Plateau. It has been our pleasure to share this beautiful area and its interesting history with you.

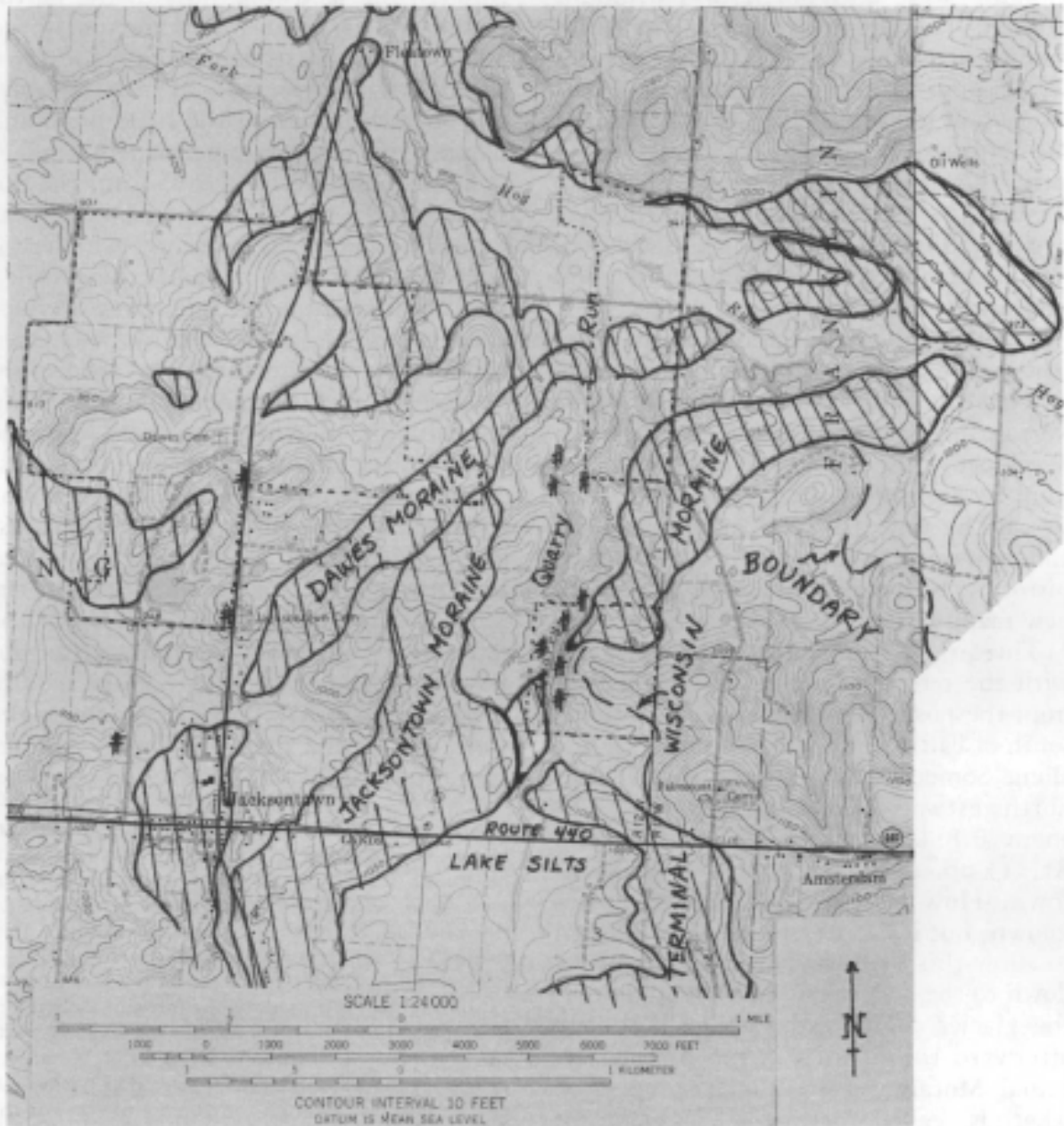


FIGURE 2. Wisconsin End Moraines on the properties of The Dawes Arboretum and adjacent landowners. Land between end moraines is ground moraine, thin till on sandstone hills, except for the southeast corner, where Illinoian ground moraine and lake silts are present. (Wisconsin boundary at east edge of map courtesy of Robert Parkinson, Soil Conservation Service soil scientist in Licking Co.) Locations of bedrock exposures marked by the symbol #.

(From Forsyth, 1983)

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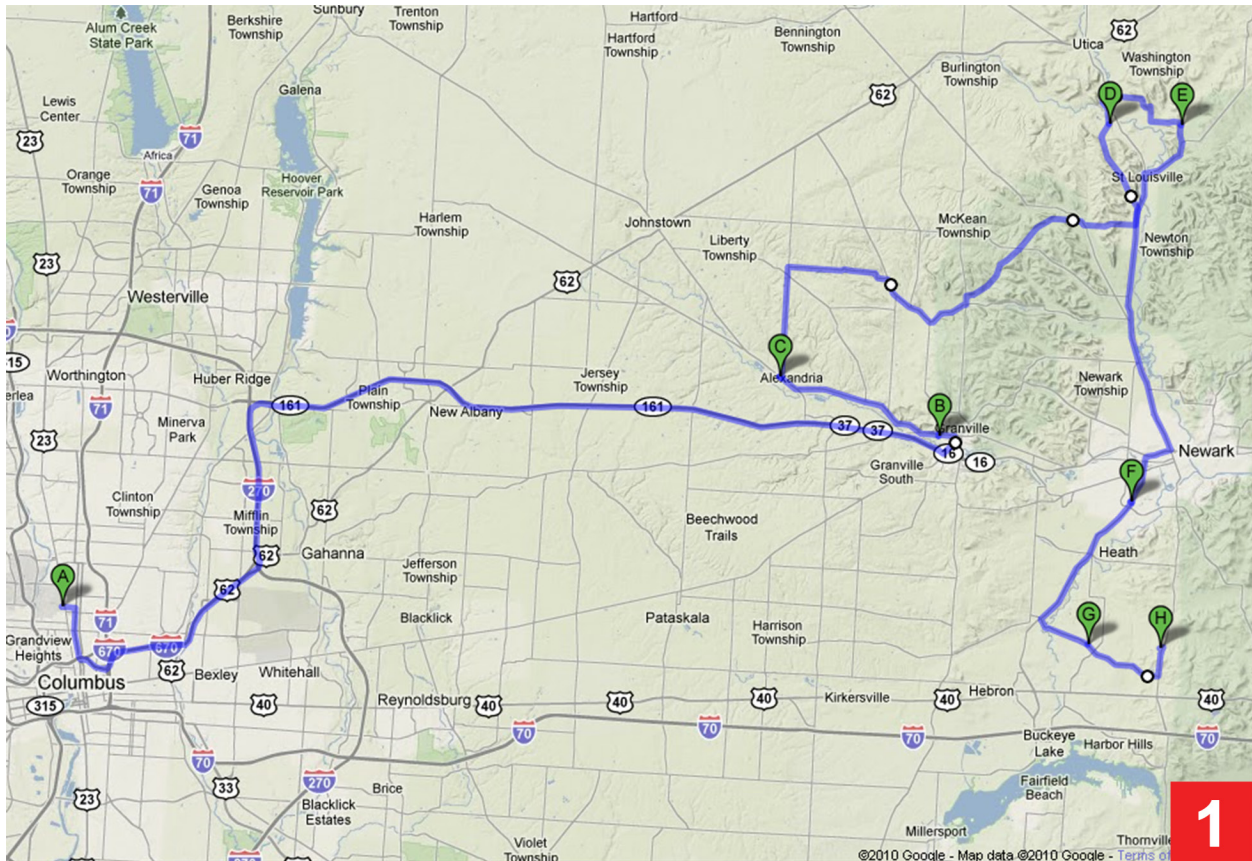
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Appendices

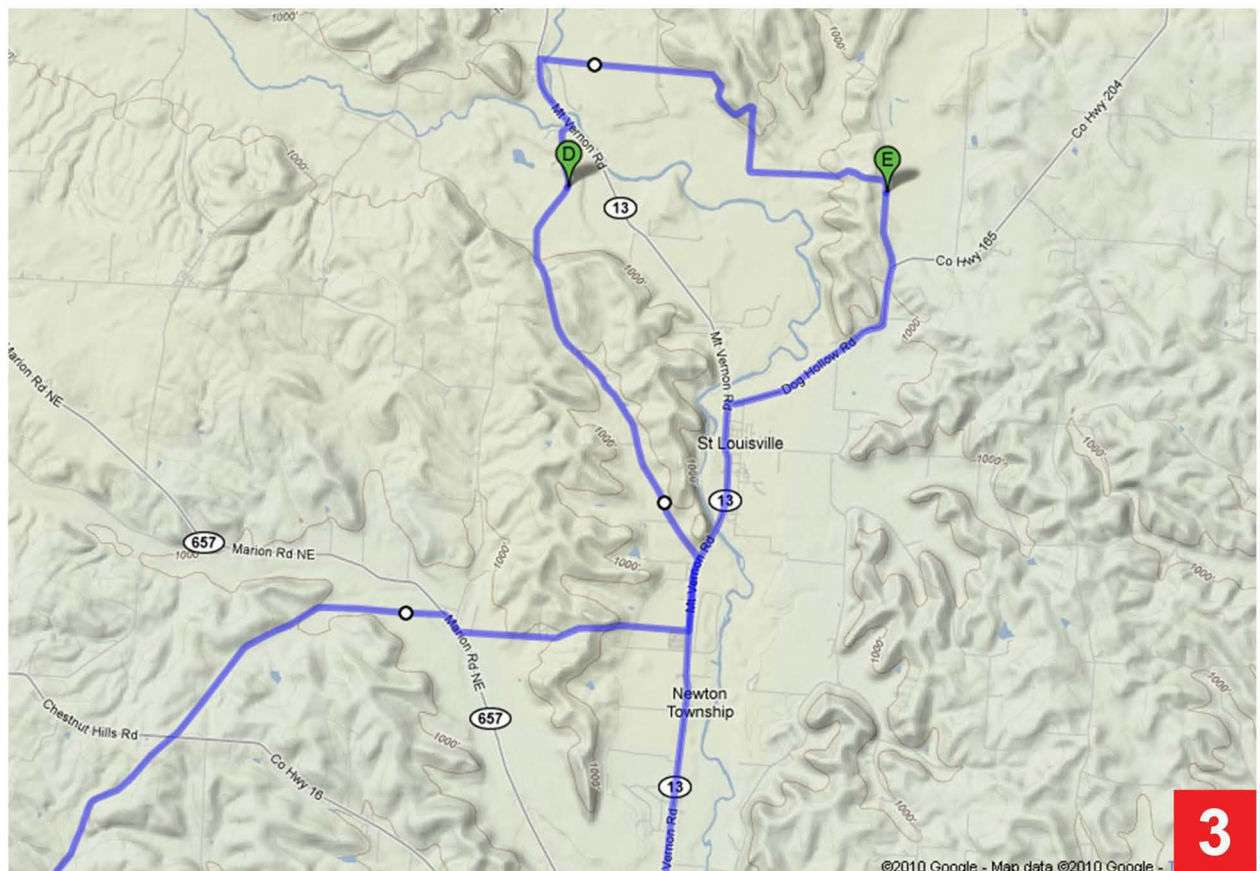
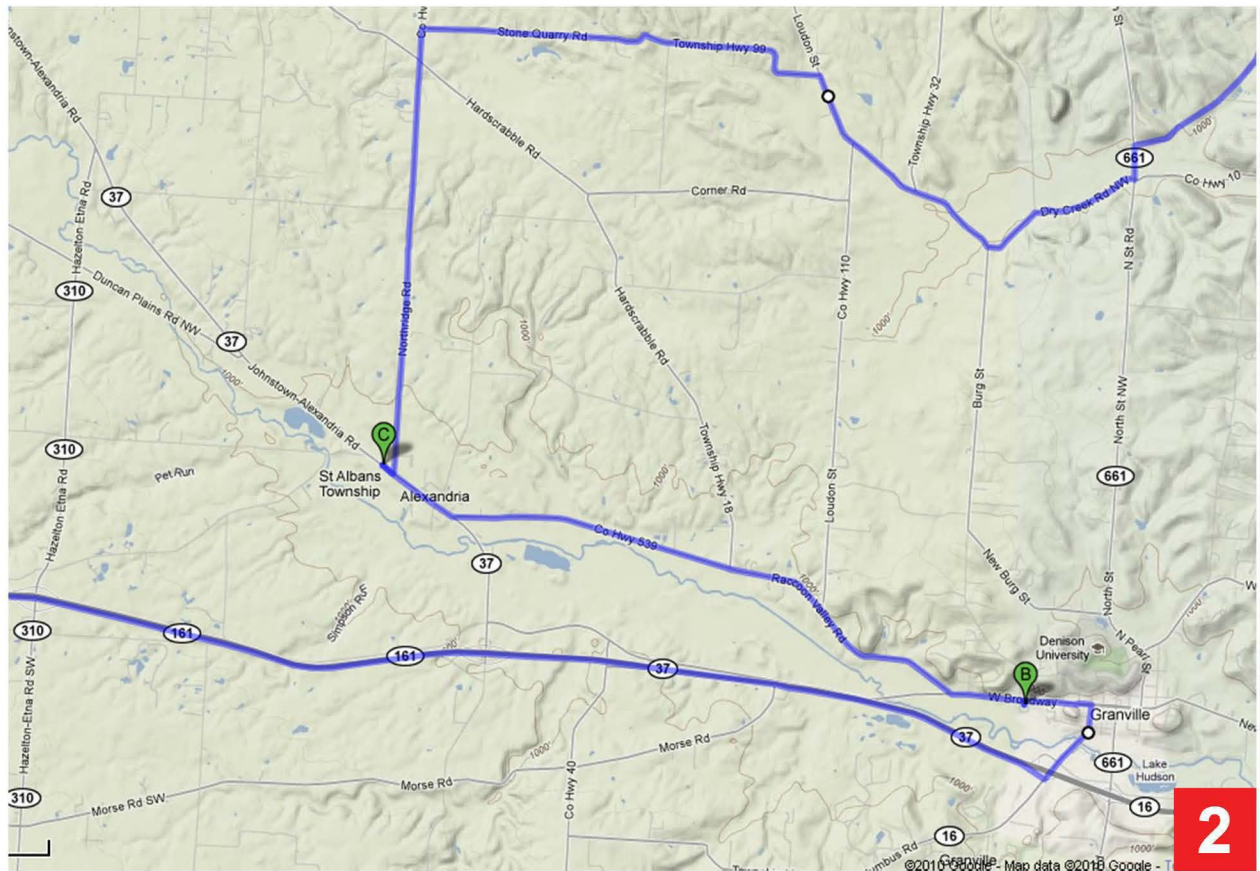
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| Appendix 1 | Field trip route map and turn by turn guide |
| Appendix 2 | Selected portions of Glacial Geology of Licking County Map, Jane L. Forsythe, 1966 |
| Appendix 3 | Shaded elevation map of Ohio |
| Appendix 4 | Glacial map of Ohio |
| Appendix 5 | Shaded bedrock-topography map of Ohio |
| Appendix 6 | Shaded drift-thickness map of Ohio |
| Appendix 7 | Map of the Newark earthworks |

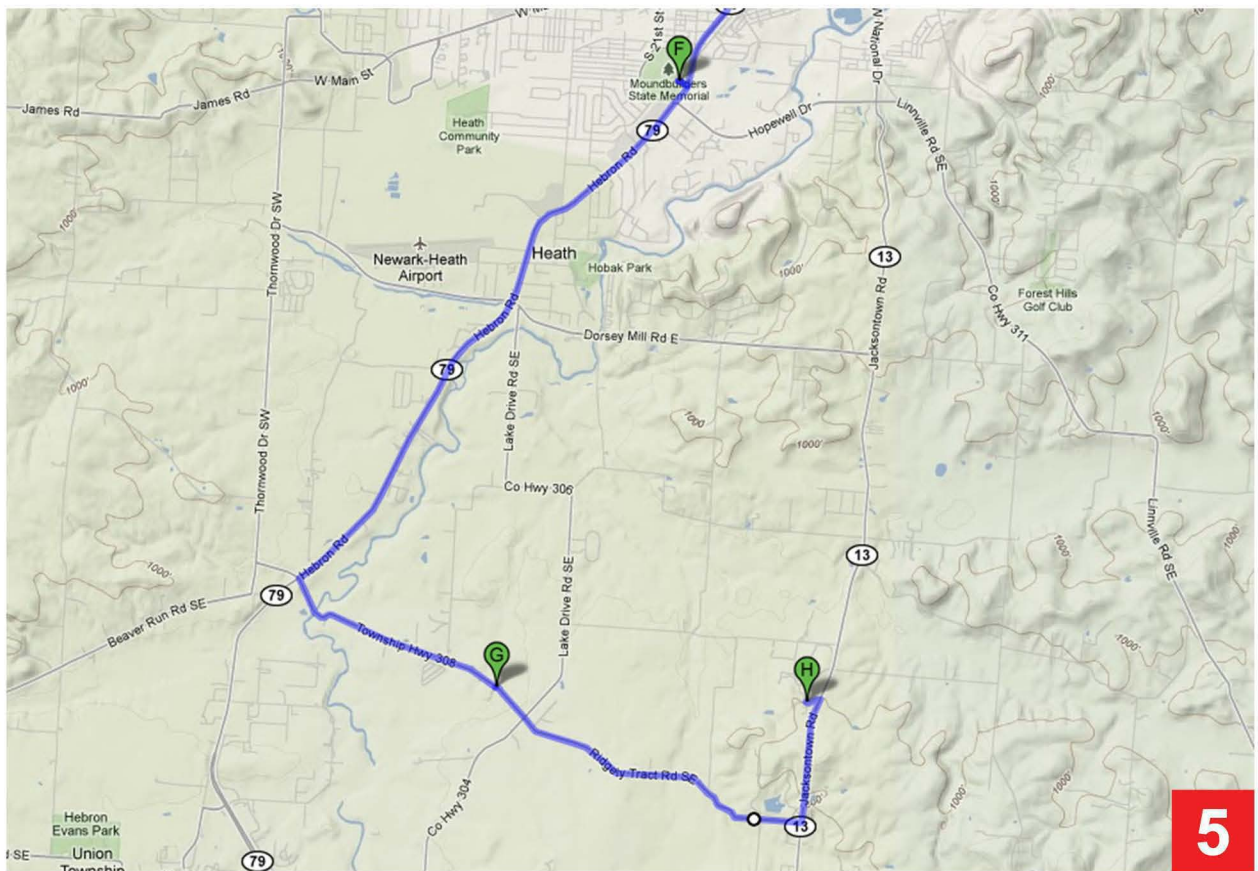
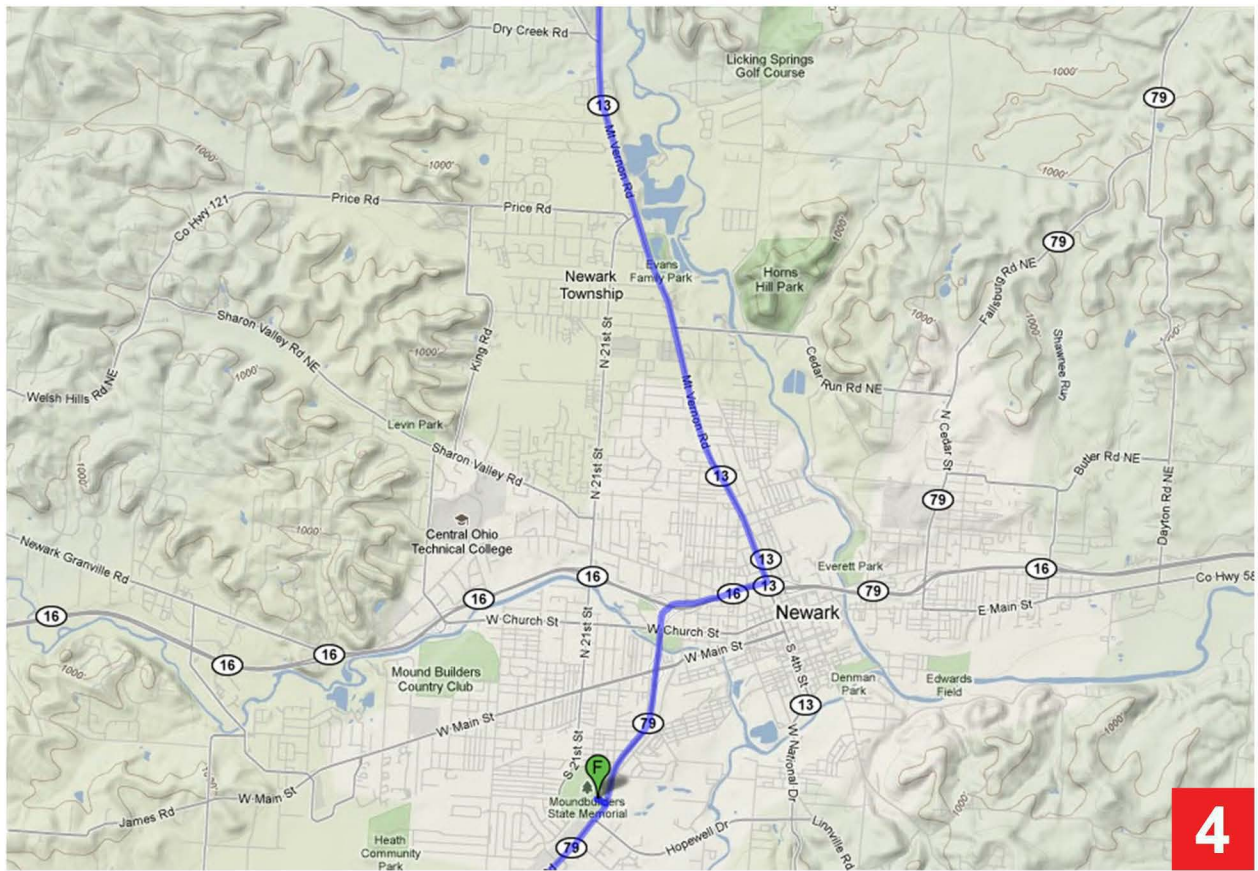
APPENDIX 1

Field Trip Route Map and Turn by Turn Guide



A map showing the route the bus will take during the field trip. Note that the area for each stop is enlarged on the maps that follow this one.





Visualizing Changing Landscape Field Trip Route Description:

A Turn by Turn Guide

Mileage log begins at Wildwood Park, West Broadway, Granville, Ohio and ends at Dawes Arboretum, located on SR 13 south of Newark, Ohio.

Route Starting Point

STOP A

New Student Union, 1739 N High Street

(About 40 minutes to Stop B)

Miles:

0.0 West on Broadway, Granville OH

STOP B

0.4 Right onto Raccoon Valley Rd.

4.2 Right onto SR 37

4.8 Left into Brookside Materials

STOP C

5.1 U turn

5.4 Right onto SR 37

5.5 Left onto Northridge Rd.

8.6 Right onto Stone Quarry Rd.

11.5 Right onto Loudon Street Rd.

12.0 Straight onto Dry Creek Rd.

13.3 Bear Left at stop

14.4 Left onto SR 661

14.7 Right onto Chatham Rd.

18.8 Right onto SR 657

19.0 Left onto St. Joseph Rd.

20.5 Left onto SR 13

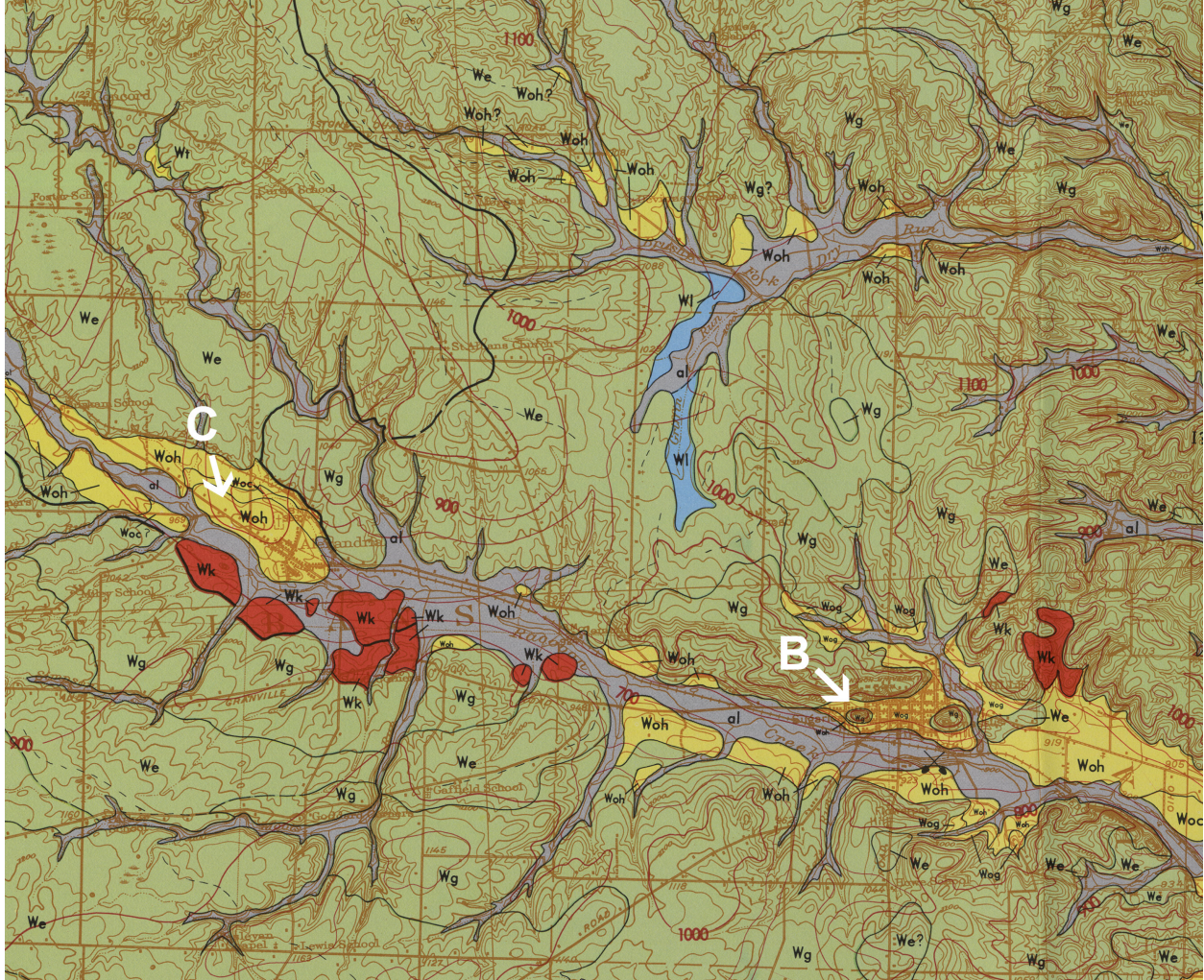
20.9 Left onto Weaver Rd.

23.2	Straight onto Smoot Rd. (unmarked)	
23.7	Smoot Lake Kame and Kettle	STOP D
24.0	Left onto SR 13	
24.5	Right onto Ginger Hill Rd.	
25.2	Cross unguarded rail road tracks	
27.2	Right onto Peat Moss Rd.	STOP E
27.8	Right onto Dog Hollow Rd.	
29.3	L onto SR 13	
37.3	Right onto SR 79	
39.4	Right into Newark Earthworks State Memorial	STOP F
39.5	Exit Right onto SR 13	
42.0	Canal Memorial on Left	
43.8	Left onto Ridgley tract Rd.	
45.3	Burning Tree Golf Course	STOP G
47.5	Right onto Licking Trails Rd.	
48.2	Left onto US 40	
48.5	Left onto SR 13	
49.9	Left into Dawes Arboretum	STOP H - Final Stop and Dinner
	Return to Columbus after dinner	

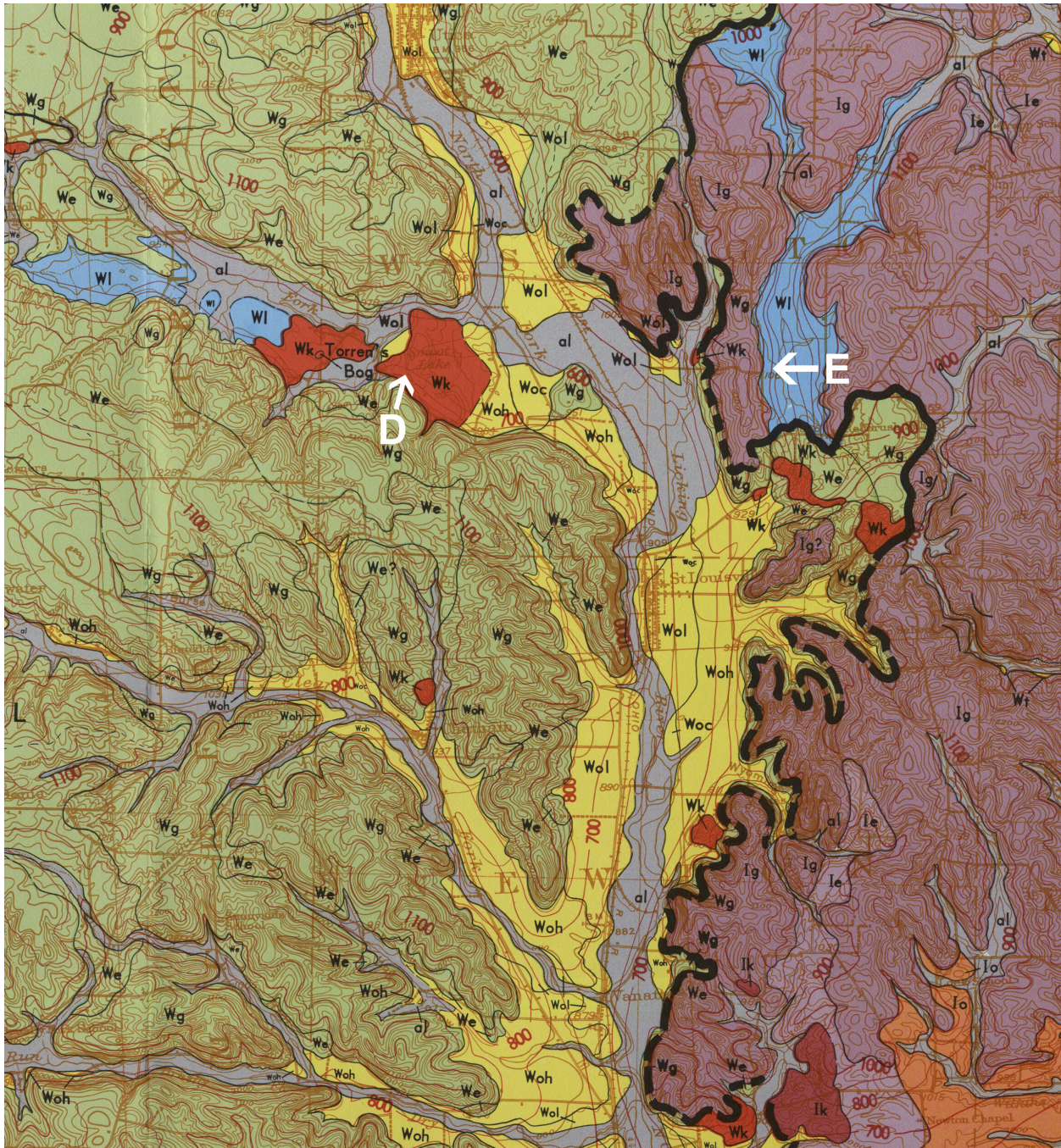
APPENDIX 2

Selected Portions of Glacial Geology of Licking County Map, Jane L. Forsythe, 1966

(The map legend is located after map 4 in this section)



Granville – Alexandria Area – Stops B and C on field trip.



St. Louisville area – Stops D and E on field trip.

EXPLANATION

RECENT



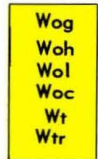
Stream alluvium

PLEISTOCENE

WISCONSIN



Lake deposits



Outwash terraces
 Wog - Granville Terrace
 Woh - Vanatta Terrace (high terrace)
 Wol - Utica Terrace (low terrace)
 Woc - low-level cut terrace
 Wt - undifferentiated Wisconsin terrace
 Wtr - terrace cut into rock



Kames



End moraines



Ground moraine

ILLINOIAN



Lake deposits



Io - outwash terrace
 Iokt - local kame terrace
 It - undifferentiated Illinoian terrace



Kames



End moraines



Ground moraine

SYMBOLS



Unglaciaded areas



Crestlines of end moraines



Line marking boundary of Wisconsin or Illinoian deposits



Line marking soil boundary within area of Wisconsin deposits



Position of pre-Wisconsin or pre-Illinoian divide



Contours drawn on bedrock surface. Contour interval 100 feet



Gravel pit

Legend for the previous four glacial maps in Appendix 2.

APPENDIX 3

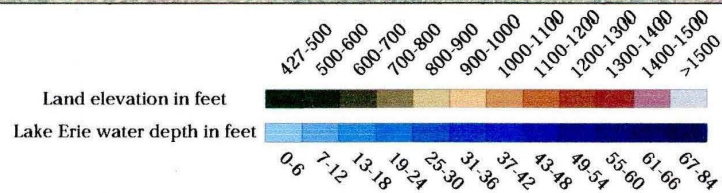
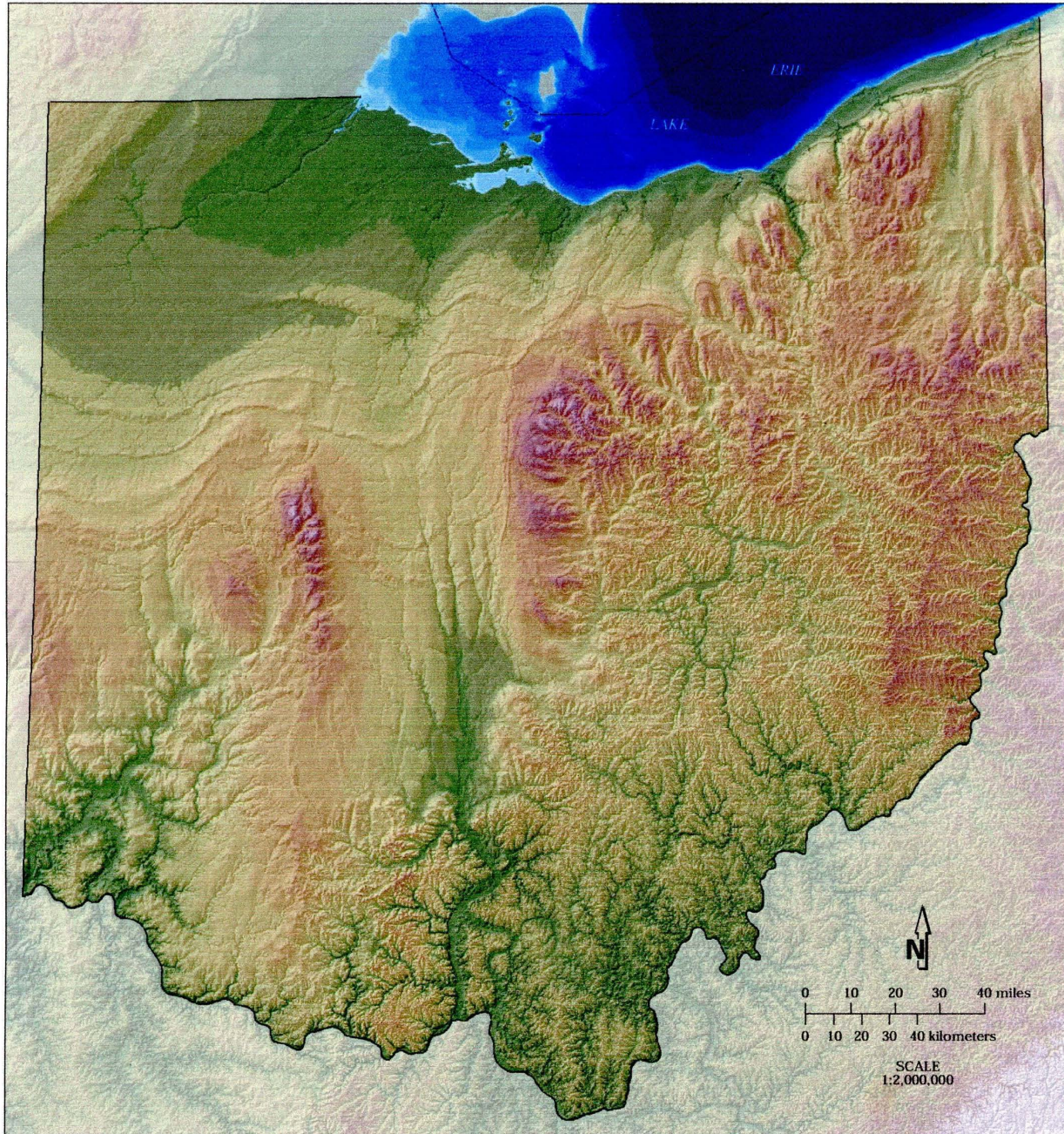
Shaded Elevation Map of Ohio

STATE OF OHIO
Ted Strickland, Governor

DEPARTMENT OF NATURAL RESOURCES
Sean D. Logan, Director

DIVISION OF GEOLOGICAL SURVEY
Lawrence H. Wickstrom, Chief

SHADED ELEVATION MAP OF OHIO

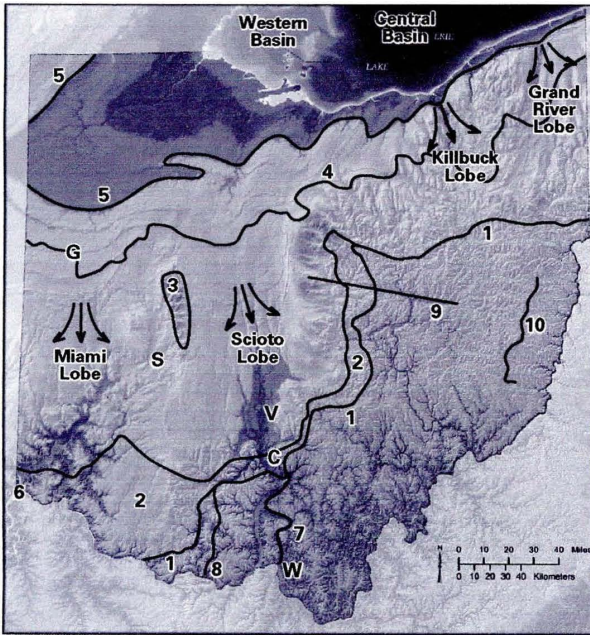


Recommended citation: Ohio Division of Geological Survey, 2002 (2003), Shaded elevation map of Ohio—earth tone version; Ohio Department of Natural Resources, Division of Geological Survey Map MG-1, generalized page-size version with text, 2 p., scale 1:2,000,000.



SHADED ELEVATION MAP

This map depicts the topographic relief of Ohio's landscape using color to represent elevation intervals. The colorized topography has been digitally shaded from the northwest slightly above the horizon to give the appearance of a three-dimensional surface. The map is based on elevation data from the U.S. Geological Survey's National Elevation Dataset; the grid spacing for the data is 30 meters. Lake Erie water depths are derived from National Oceanic and Atmospheric Administration data. This digitally derived map shows details of Ohio's topography unlike any map of the past. Some of Ohio's more striking topographic features are outlined on the inset map below and described in the following paragraphs.



Direction of ice flow in glacial lobes
C = Chillicothe
G = Grand Lake St. Marys
S = Springfield
V = Circleville
W = Wheelersburg

1 Glacial boundary—Continental ice sheets several thousand feet thick sculpted about two-thirds of Ohio's landscape and, upon melting, deposited material formerly incorporated in or beneath the ice. This boundary marks the southernmost known extent of glacial ice in Ohio. Topography in the glaciated portion of Ohio is smooth compared to the highly dissected, unglaciated part of Ohio. The glacial boundary in eastern Ohio is farther north than the boundary in western Ohio because the erosion-resistant bedrock hills in eastern Ohio impeded southward glacial advances. The glacial boundary in central and southwestern Ohio typically represents the maximum advance of Illinoian-age (130,000-300,000 years ago) glaciers. The east-west-oriented boundary in northeastern Ohio represents the maximum advance of Wisconsinan-age (14,000-24,000 years ago) glaciers.

2 Illinoian till areas—Thin till (an unsorted mixture of glacially deposited clay, silt, sand, and cobbles) of Illinoian age is at the surface in a 10- to 40-mile-wide belt between the Illinoian and Wisconsinan maximum advances. Terrain in this belt is typically transitional between the generally flat Wisconsinan till plains to the north and west and the dissected, unglaciated bedrock to the southeast. The surface deposits in this belt are characterized by loess (wind-blown silt) over thin till on ridge tops and thick colluvium (weathered bedrock) on slopes.

3 Ohio's highest elevation—An upland area known as the Bellefontaine Outlier covers portions of Champaign, Logan, and Union Counties in west-central Ohio. The outlier is an erosional remnant of Devonian-age limestone, dolomite, and shale that lies 25 miles west of the main outcrop belt of Devonian-age rock in Franklin and Delaware Counties in central Ohio. The outlier is mantled by up to 160 feet of till, which adds to the outlier's height. Campbell Hill, the highest elevation in Ohio at 1,549 feet above sea level, is on the outlier. The higher, more resistant bedrock of the out-

lier impeded the southward-advancing glaciers, causing them to split into two lobes, the Miami Lobe on the west and the Scioto Lobe on the east. Ridges of thick accumulations of glacial material, called moraines, drape around the outlier and are distinct features on the map. Some moraines in Ohio are more than 200 miles long. Two other glacial lobes, the Killbuck and the Grand River Lobes, are present in the northern and northeastern portions of the state.

4 Eastern Continental Divide—A continental drainage divide extends east-west across northern Ohio. Surface water north of this divide flows northward to Lake Erie, eventually over Niagara Falls into Lake Ontario, and into the Atlantic Ocean. Surface water south of the divide flows south to the Ohio River, the Mississippi River, and eventually into the Gulf of Mexico. The divide follows the crests of glacial moraines in western Ohio. In north-central and northeastern Ohio, the divide follows bedrock-controlled hills and glacial valleys containing thick glacial-lake deposits.

5 Ancient Lake Maumee shoreline—About 14,000 years ago, the last continental ice sheet retreated northward across Ohio. The St. Lawrence Seaway was blocked by glacial ice, and glacial meltwater created lakes in front of the ice. A large lake, called Lake Maumee, formed in the general position of Lake Erie but extended over a much larger portion of northwestern Ohio. Ancient Lake Maumee water levels were about 230 feet higher than modern Lake Erie, and drained westward into the Wabash River system. The shoreline of ancient Lake Maumee had a series of sandy beaches and beach scarps, much like portions of Lake Erie today. The ancient sandy beaches are visible on the map as long, thin ridges on the surrounding flat lake terrain. Other beach ridges formed as the water level receded in stages before rising to its current level of approximately 572 feet above sea level. Lake Erie is the shallowest of the Great Lakes and has three basins: the western (averages 30 feet in depth), central (averages 60 feet in depth), and eastern (not shown on map; averages 80 feet in depth; maximum depth is about 212 feet).

6 Ohio's lowest elevation—The lowest surface elevation in Ohio is about 455 feet above sea level and is located where the Ohio River exits the state at the extreme southwestern corner of Ohio.

7 Teays River valley—The ancient Teays River flowed across Ohio before and during the earliest Ice Age. A north-south-trending remnant of the Teays River valley in south-central Ohio is distinctly visible on this map. From its headwaters in North Carolina, the Teays River flowed northwest across Virginia and West Virginia and entered Ohio in the area of present-day Wheelersburg. The Teays River cut a wide, curving valley as it flowed northward through southern Ohio. This valley, partially filled with clay, silt and sand, contains only a small stream today and remains clearly visible on the map as far as Chillicothe. North of Chillicothe, the valley is buried beneath hundreds of feet of glacial sediment but can be traced using well data to Circleville; the buried valley then turns northwestward, passing beneath Springfield and Grand Lake St. Marys and into eastern Indiana. In parts of western Ohio, the valley lies beneath 700 feet of glacially derived material. The valley commonly is about 200 to 300 feet deep and has steep to near-vertical walls.

8 Allegheny Escarpment—Beyond the glacial boundary, the Allegheny Escarpment of southern Ohio marks a distinct change in topography. The land surface changes abruptly from the flatter, lower terrain in the west, which is underlain by soft carbonate rocks, to the higher, steeper terrain in the east, which is underlain by shale and sandstone. To the north, the escarpment was affected by glaciation, making it a less distinct topographic feature. The Allegheny Escarpment corresponds to a slight increase in the dip (tilt) of the rock layers as they descend eastward into the Appalachian Basin.

9 Surface lineament—A west-northwest-trending lineament (a linear topographic feature on the Earth's surface) across east-central Ohio is distinctly visible on the map. The Walhonding River and a portion of the Muskingum River flow in portions of this linear topographic depression. Although poorly understood, this feature, which is referred to as the Coshocton Fracture Zone, has been attributed to fractures in the surface bedrock that are possibly related to faults present deeper in the subsurface.

10 Flushing Divide—A sharp, north-northeast-trending, ridgelike feature in eastern Ohio is the Flushing Drainage Divide, named after the Belmont County village of Flushing, where it is well developed. Surface water west of the divide flows westward into a series of low-gradient creeks, such as the Sandy, Conotton, and Stillwater, and then to the Tuscarawas River. Surface water east of the divide flows eastward into a series of high-gradient, rapidly down-cutting creeks that flow into the Ohio River. The ridge is at an elevation of about 1,260 to 1,280 feet above sea level and separates two old Teays-era drainage basins.

APPENDIX 4

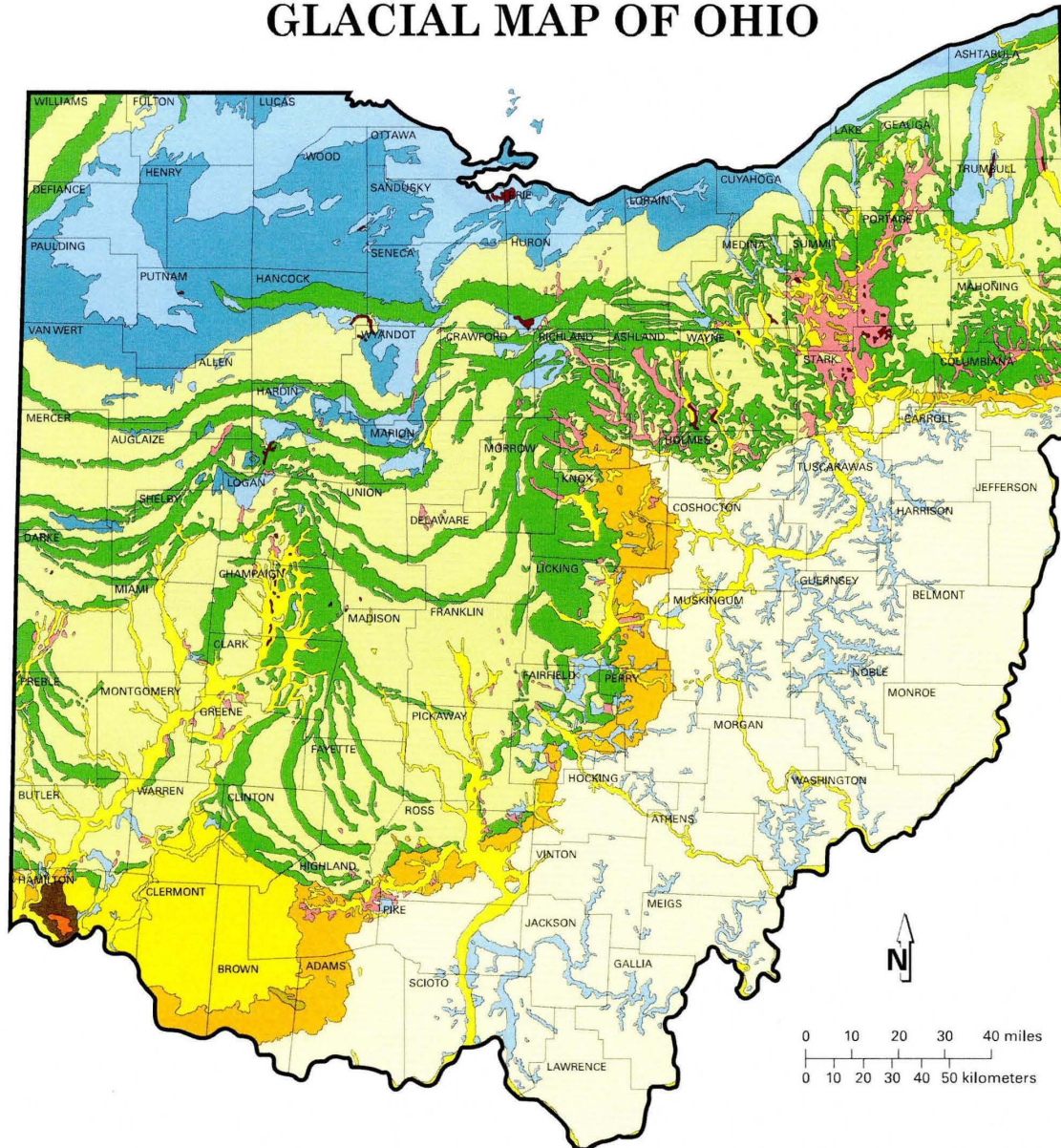
Glacial Map of Ohio

STATE OF OHIO
Ted Strickland, Governor

DEPARTMENT OF NATURAL RESOURCES
Sean D. Logan, Director

DIVISION OF GEOLOGICAL SURVEY
Lawrence H. Wickstrom, Chief

GLACIAL MAP OF OHIO



WISCONSINAN (14,000 to 24,000 years old)	ILLINOIAN (130,000 to 300,000 years old)	PRE-ILLINOIAN (older than 300,000 years)	
Ground moraine	Ground moraine	Ground moraine	Kames and eskers
Wave-planed ground moraine	Dissected ground moraine	Dissected ground moraine	Outwash
Ridge moraine	Hummocky moraine		Lake deposits
			Peat
			Colluvium



Recommended citation: Ohio Division of Geological Survey, 2005, Glacial map of Ohio: Ohio Department of Natural Resources, Division of Geological Survey, page-size map with text, 2 p., scale 1:2,000,000.



GLACIAL DEPOSITS OF OHIO

Although difficult to imagine, Ohio has at various times in the recent geologic past (within the last 1.6 million years) had three-quarters of its surface covered by vast sheets of ice perhaps as much as 1 mile thick. This period of geologic history is referred to as the Pleistocene Epoch or, more commonly, the Ice Age, although there is abundant evidence that Earth has experienced numerous other "ice ages" throughout its 4.6 billion years of existence.

Ice Age glaciers invading Ohio formed in central Canada in response to climatic conditions that allowed massive buildups of ice. Because of their great thickness, these ice masses flowed under their own weight and ultimately moved south as far as northern Kentucky. Oxygen-isotope analysis of deep-sea sediments indicates that more than a dozen glaciations occurred during the Pleistocene. Portions of Ohio were covered by the last two glaciations, known as the Wisconsinan (the most recent) and the Illinoian (older), and by an undetermined number of pre-Illinoian glaciations.

Because each major advance covered deposits left by the previous ice sheets, pre-Illinoian deposits are exposed only in extreme southwestern Ohio in the vicinity of Cincinnati. Although the Illinoian ice sheet covered the largest area of Ohio, its deposits are at the surface only in a narrow band from Cincinnati northeast to the Ohio-Pennsylvania border. Most features shown on the map of glacial deposits of Ohio are the result of the most recent or Wisconsinan-age glaciers.

The material left by the ice sheets consists of mixtures of clay, sand, gravel, and boulders in various types of deposits of different modes of origin. Rock debris carried along by the glacier was deposited in two principal fashions, either directly by the ice or by meltwater from the glacier. Some material reaching the ice front was carried away by streams of meltwater to form outwash deposits. Material deposited by water on and under the surface of the glacier itself formed features called kames and eskers, which are recognized by characteristic shapes and composition. A distinctive characteristic of glacial sediments that have been deposited by water is that the material was sorted by the water that carried it. Thus, outwash, kame, and esker deposits normally consist of sand and gravel. The large boulder-size particles were left behind and the smaller clay-size particles were carried far away, leaving the intermediate gravel- and sand-size material along the stream courses.

Material deposited directly from the ice was not sorted and ranges from clay to boulders. Some

of the debris was deposited as ridges parallel to the edge of the glacier, forming terminal or end moraines, which mark the position of the ice when it paused for a period of time, possibly a few hundred years. When the entire ice sheet receded because of melting, much of the ground-up rock material still held in the ice was deposited on the surface as ground moraine. The oldest morainic deposits in Ohio are of Illinoian and pre-Illinoian age. Erosion has significantly reduced these deposits along the glacial boundary, leaving only isolated remnants that have been mapped as dissected ground moraine and hummocky moraine.

Many glacial lakes were formed in Ohio during the Ice Age. Lake deposits are primarily fine-grained clay- and silt-size sediments. The most extensive area of lake deposits is in northern Ohio bordering Lake Erie. These deposits, and adjacent areas of wave-planed ground moraine, are the result of sedimentation and erosion by large lakes that occupied the Erie basin as Wisconsinan-age ice retreated into Canada. Other lake deposits accumulated in stream valleys whose outlets were temporarily dammed by ice or outwash. Many outwash-dammed lake deposits are present in southeastern Ohio far beyond the glacial boundary. Peat deposits are associated with many lake deposits and formed through the accumulation of partially decayed aquatic vegetation in oxygen-depleted, stagnant water.

The term glacial drift commonly is used to refer to any material deposited directly (*e.g.*, ground moraine) or indirectly (*e.g.*, outwash) by a glacier. Because the ice that invaded Ohio came from Canada, it carried in many rock types not found in Ohio. Pebbles, cobbles, and boulders of these foreign rock types are called erratics. Rock collecting in areas of glacial drift may yield granite, gneiss, trace quantities of gold, and very rarely, diamonds. Most rocks found in glacial deposits, however, are types native to Ohio.

Certain deposits left behind by the ice are of economic importance, particularly sand and gravel, clay, and peat. Sand and gravel that have been sorted by meltwater generally occur as kames or eskers or as outwash along major drainageways. Sand and gravel are vital to Ohio's construction industry. Furthermore, outwash deposits are among the state's most productive sources of ground water.

Glacial clay is used in cement and for common clay products (particularly brick). The minor quantities of peat produced in the state are used mainly for mulch and soil conditioning.

APPENDIX 5

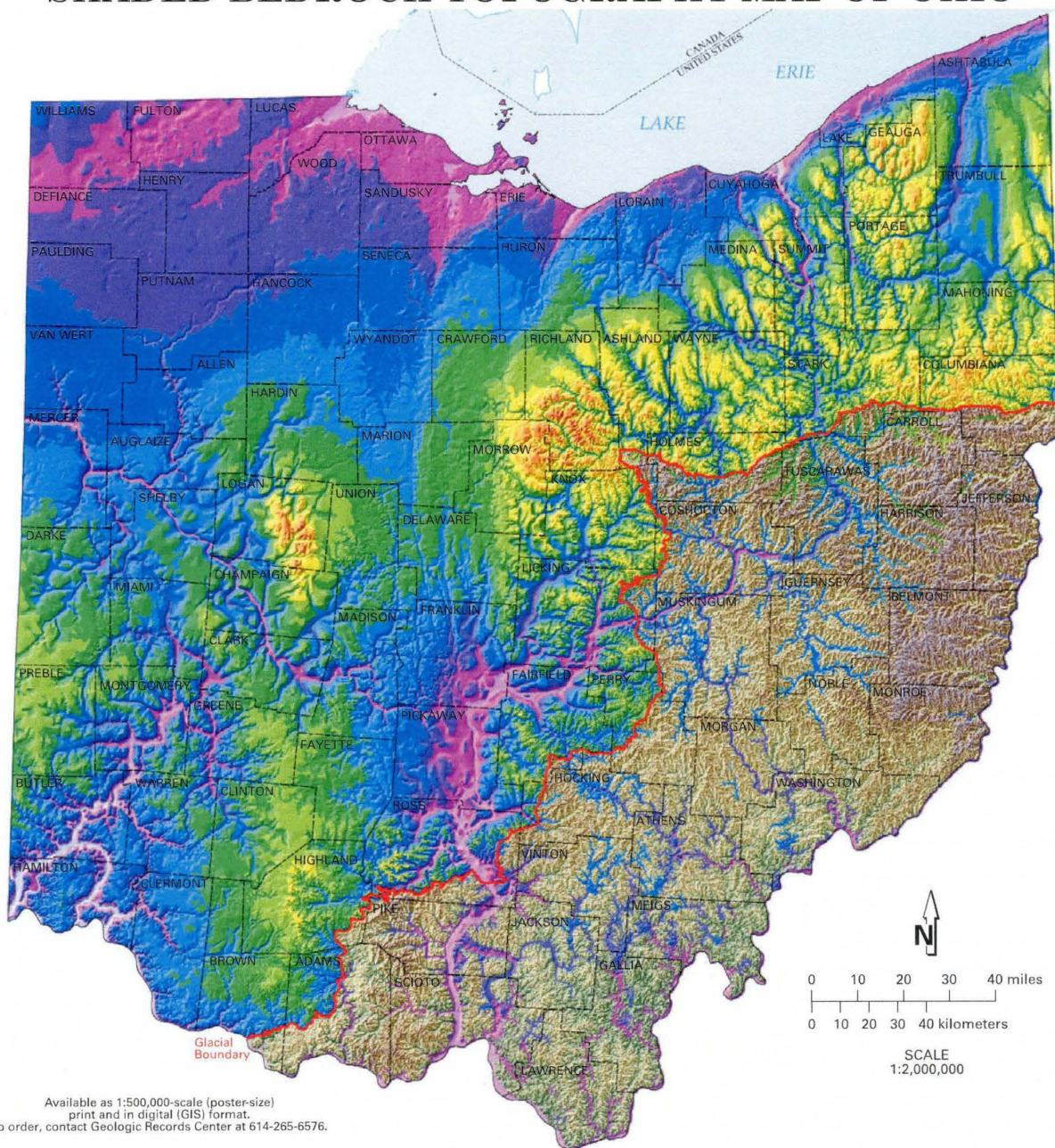
Shaded Bedrock-Topography Map of Ohio

STATE OF OHIO
Ted Strickland, Governor

DEPARTMENT OF NATURAL RESOURCES
Sean D. Logan, Director

DIVISION OF GEOLOGICAL SURVEY
Lawrence H. Wickstrom, Chief

SHADED BEDROCK-TOPOGRAPHY MAP OF OHIO



Bedrock-topography	Elevation	Land surface
	1401-1500	
	1301-1400	
	1201-1300	
	1101-1200	

Bedrock-topography	Elevation	Land surface
	1001-1100	
	901-1000	
	801-900	
	701-800	

Bedrock-topography	Elevation	Land surface
	601-700	
	501-600	
	401-500	
	301-400	

Elevation in feet above sea level

Recommended citation: Ohio Division of Geological Survey, 2003, Shaded bedrock-topography map of Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map BG-3, generalized page-size version with text, 2 p., scale 1:2,000,000.



SHADED BEDROCK-TOPOGRAPHY MAP OF OHIO

The shaded bedrock-topography map of Ohio depicts the configuration and elevation of the bedrock surface. In southeastern Ohio, the bedrock surface coincides with present-day land-surface topography and is depicted by earth-tone hues to represent elevation intervals. In glaciated western and northern Ohio, the bedrock surface is buried under mainly glacial sediments that can be several-hundred-feet thick. The land surface in this region was smoothed by glaciation (figure 1) and masks a complexly dissected, underlying bedrock surface. This dissected bedrock surface is the result of erosion before, during, and after glaciation. Spectral hues depict elevation intervals on the buried-bedrock surface and show the bedrock surface as if the overlying glacial sediment were removed.

Prior to and during glaciation, the north-flowing Teays River system dominated surface-water drainage patterns in western and southern Ohio (figure 2). Water flow direction in the main Teays valley was north from Wheelersburg (Scioto County) to Circleville (Pickaway County) and then northwest to Mercer County where the Teays Valley exited the state. Remnants of the Teays Valley are distinct on the present land surface in southern Ohio and form a continuous valley on the buried-bedrock surface across western Ohio. Modern rivers and streams still occupy portions of this valley system. Water flow in the Teays River system was disrupted by early glaciations as southward-advancing glaciers blocked outlets of the north-flowing river system. Drainageways, both large and small, were abandoned or filled with sediment as ice advanced and retreated.

In northwestern Ohio, the generally smooth buried-bedrock surface is the result of repeated scouring by glacial ice advancing westward out of the Lake Erie basin. Another distinctly scoured bedrock surface is in the Grand River Lobe (figure 2) in northeastern Ohio where smooth north-south trending valleys mirror ice-flow direction. South of the scour-dominated surface of northern Ohio, the bedrock surface has been sculpted by water to create a distinct drainage pattern (figure 2). Large volumes of glacial meltwater eroded the bedrock surface, widening and deepening existing valleys of the Teays system and creating new valleys. Some modern rivers and creeks flow in unusually wide valleys; evidence that far greater volumes of water generated from melting glaciers once flowed in these valleys. Flow direction in other valleys has been reversed as glacial ice or glacial sediments blocked formerly northward and westward flowing streams.

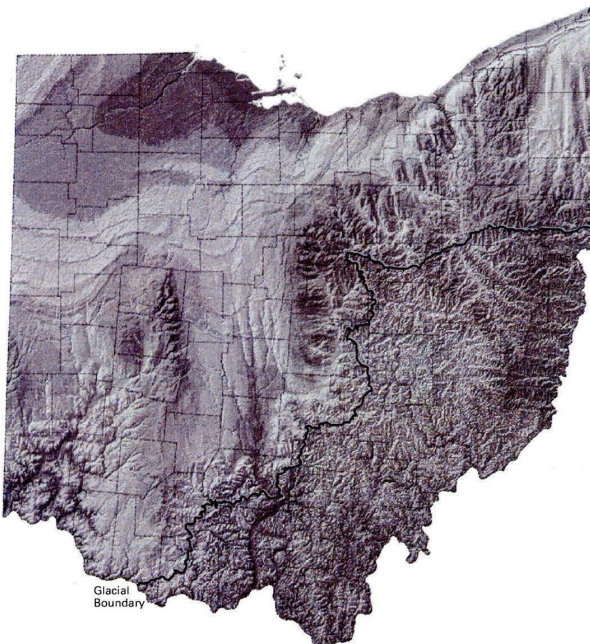


FIGURE 1.—Shaded elevation map of Ohio with the glacial boundary. Note the smooth landscape of glaciated northern and western Ohio compared to the high-relief landscape of unglaciated southeastern Ohio.

Southeastern Ohio is unglaciated and devoid of ice-deposited sediment (glacial till). However, many river valleys in southeast Ohio did carry glacial meltwater away from the ice front and toward the Ohio River. In the process, many of these valleys were at times made deeper by the erosive force of fast-flowing meltwater streams, and at other times partially filled with sediment. Some valleys in unglaciated Ohio contain thick deposits of clay and silt that accumulated on the bottoms of lakes that formed when glacial ice blocked the flow of rivers or when rapidly accumulating meltwater sediments blocked the mouths of rivers.

This map is one of the results of a 7-year effort by the ODNR, Division of Geological Survey to map the bedrock geology of Ohio. Bedrock-topography maps are essential to producing accurate bedrock-geology maps of glaciated Ohio and of partially buried valleys beyond the glacial limit. Bedrock-topography maps were created for all 788 7.5-minute topographic quadrangles in the state and are available from the Division's Geologic Records Center. Some pre-existing county bedrock-topography maps (1:62,500 scale) and data were photographically enlarged to 1:24,000 scale, revised, and utilized in the compilation of 1:24,000-scale, bedrock-topography maps. Data concentration and contour intervals on the original maps vary widely across the state in response to changing geologic and topographic conditions. Data consists mainly of water-well logs on file at the ODNR, Division of Water, supplemented by outcrop data, Ohio Department of Transportation bridge-boring data, and oil-and-gas-well data.

Elevation contours and over 158,000 data points from the 788 bedrock-topography maps were digitized and compiled for the glaciated portions of the state and for the major valleys beyond the glacial boundary containing significant accumulations of sediment deposited during and after glaciation. The bedrock-topography contours were digitally converted in the ARC GIS environment into a continuous grid model (60 meter grid spacing). This surface was shaded from the northwest slightly above the horizon to produce the appearance of a three-dimensional surface.

The land surface represents the topography of the bedrock surface in southeastern Ohio (excluding valleys beyond the glacial boundary) and in some glaciated areas near the glacial limit where meltwater sediments are thin or absent. Land-surface topography is based largely on data derived from the U.S. Geological Survey's National Elevation Dataset (30 meter grid spacing).

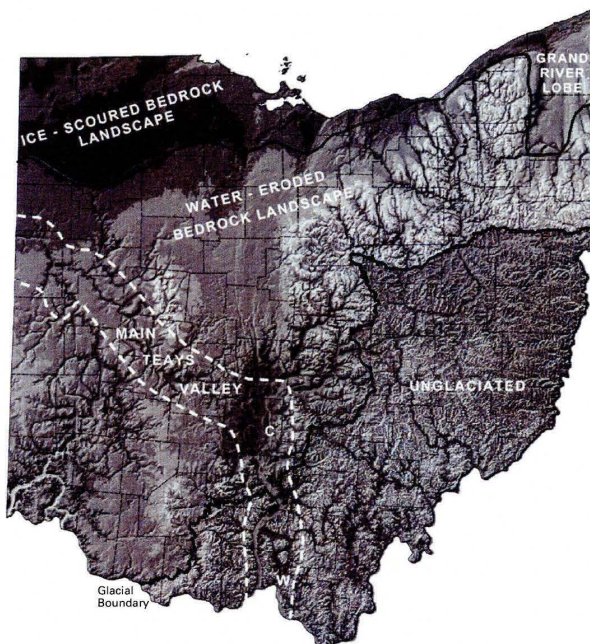


FIGURE 2.—Bedrock-topography map of Ohio showing the extent of the main Teays valley, the unglaciated portion of the state, and the ice-scoured and water-eroded portions of glaciated Ohio (C = Circleville, W = Wheelersburg).

APPENDIX 6

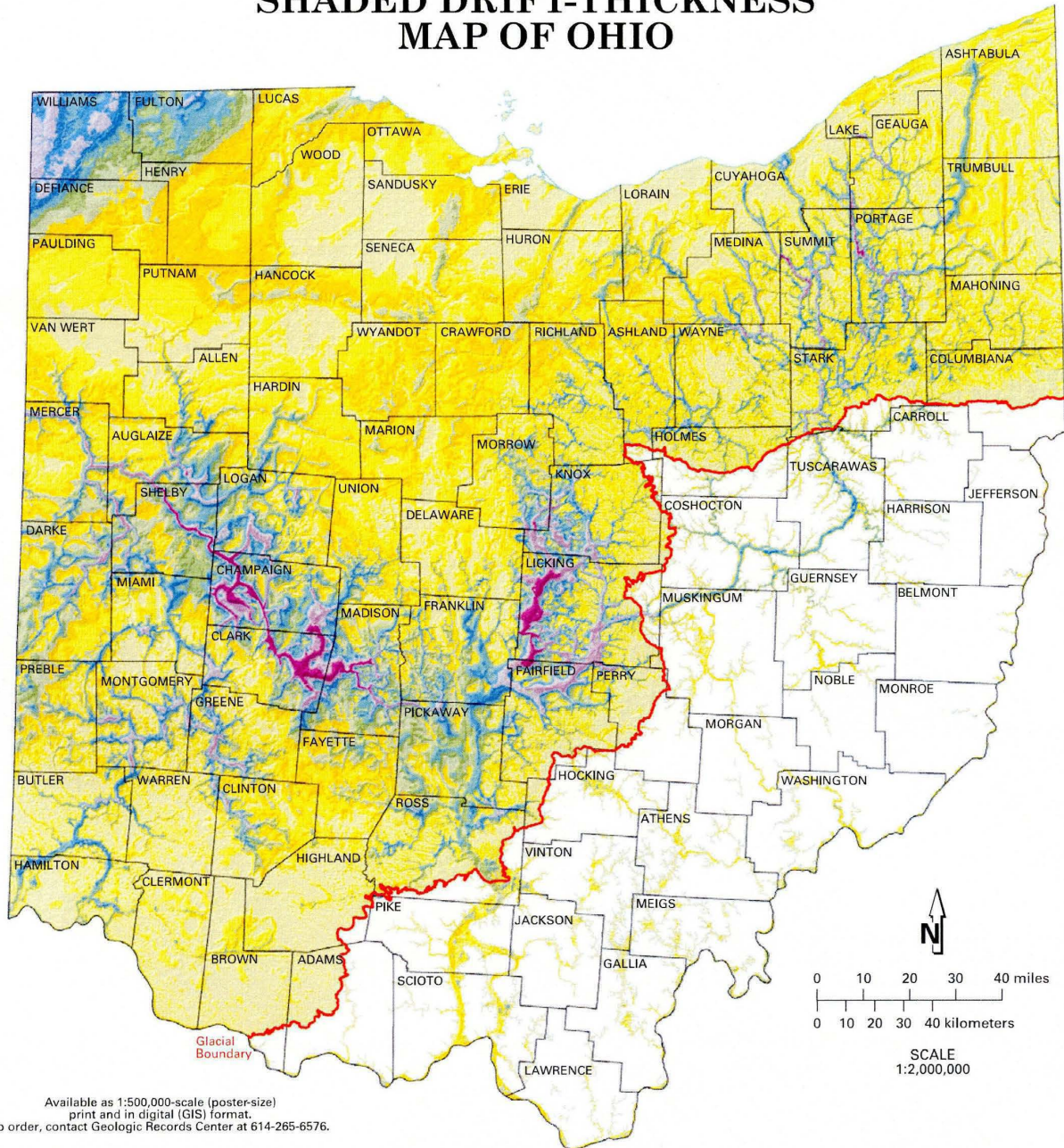
Shaded Drift-Thickness Map of Ohio

STATE OF OHIO
Ted Strickland, Governor

DEPARTMENT OF NATURAL RESOURCES
Sean D. Logan, Director

DIVISION OF GEOLOGICAL SURVEY
Lawrence H. Wickstrom, Chief

SHADED DRIFT-THICKNESS MAP OF OHIO



EXPLANATION

Thickness (in feet) of drift in glaciated areas and some non-glaciated areas along glacial boundary, and of outwash and glaciolacustrine deposits in sediment-filled valleys beyond the glacial boundary.

0 - 20	51 - 80	121 - 160	211 - 260	331 - 440
21 - 50	81 - 120	161 - 210	261 - 330	441 - 726



Recommended citation: Ohio Division of Geological Survey, 2004, Shaded drift-thickness map of Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map SG-3, generalized page-size version with text, 3 p., scale 1:2,000,000.



SHADED DRIFT-THICKNESS MAP OF OHIO

INTRODUCTION

The drift-thickness map of Ohio depicts the thickness and distribution of glacially derived sediments (called drift) and post-glacial stream sediments overlying the buried bedrock surface. This map was produced by subtracting bedrock-surface elevations from land-surface elevations to produce a residual map of drift thickness. Colors portray thickness intervals of glacial and modern sediments, which can range up to several hundred feet.

Prior to the onset of continental glaciation in the Early Pleistocene Epoch, approximately 1.8 million years before present, the Ohio landscape was dominated by rolling hills and deeply incised, mature rivers and streams. A reduced version of the Division of Geological Survey's Shaded-Bedrock Topography map of Ohio (fig. 1) reveals some aspects of this old land surface. Erosion and deposition by Ice-Age continental glaciers advancing into northern and western Ohio produced a low-relief land surface compared to the unglaciated, high-relief land surface of southeastern Ohio (fig. 2). Comparing the shaded elevation map (fig. 2) with the shaded bedrock-topography map (fig. 1) reveals the dramatic impact of glaciation on the state's current landscape.

Drift thickness in western and northern Ohio (fig. 3) is highly variable, a consequence of numerous geologic factors acting in combination or alone. In some areas, drift has been deposited on a relatively flat bedrock surface and changes in drift thickness are primarily the result of variations in the amount of glacial material deposited. In other areas, drift has infilled a deeply incised buried-bedrock surface, and changes in drift thickness are primarily the result of variations in bedrock-surface elevation. In still other instances, the drift surface parallels the underlying bedrock surface to produce areas of relatively uniform drift thickness.

Distinct, narrow linear patterns of thick drift in western and central Ohio are the result of deep incisions in the underlying limestone and

dolomite bedrock by a large, northwest flowing drainage system, the Teays Valley system, that existed prior to and during early glaciations (fig. 1). The main Teays Valley entered the state at Wheelersburg (Scioto County), where remnants of the Teays Valley are still evident on the modern land surface. At Chillicothe (Ross County), the valley disappears under glacial sediments which cover western Ohio. However, the valley continues north, below the surface, to Circleville (Pickaway County) and then northwest to Mercer County where the valley exits the state into Indiana. Early southward-advancing glaciers blocked the north-flowing river system of the Teays and created immense lakes in southeastern Ohio.

In northeastern Ohio, narrow thick-drift areas south of Lake Erie were also preglacial bedrock valleys. These valleys were partially filled with thick deposits of till and glaciolacustrine (glacial lake) sediment and then re-excavated by later northward-flowing rivers such as the Cuyahoga River and the East Branch of Rocky River.

In northwestern Ohio, repeated scouring of the relatively soft bedrock surface by glacial ice flowing southwestward from the Lake Erie Basin destroyed most pre-existing drainage systems. In this part of Ohio, the bedrock surface is smooth and the upper surface of the drift has been planed off by wave action and deposition by a post-glacial, high-level ancestral Lake Erie. In the extreme northwest corner of Ohio, in Williams County and portions of Defiance County, drift thickens considerably because of numerous moraines that formed along the northwestern edge of the Erie Lobe.

In western Ohio, draping linear features of thick drift, called ridge moraines, formed along the temporarily stationary ice-front as glacial sediment was released from the ice. These ribbons of thick drift define the lateral dimensions of glacial ice lobes, particularly those of the last Wisconsinan ice sheet (figure 4). Many ridge moraines in western and northeastern Ohio have a draped appearance because south-flowing ice, impeded by bedrock highlands, moved more easily along major lowlands. The numerous resistant bedrock highlands in northeastern Ohio caused ridge moraines to be especially arcuate and closely stacked.

Southeastern Ohio is unglaciated and devoid of ice-deposited sediment (glacial till). Many southeast Ohio valleys, however, carried

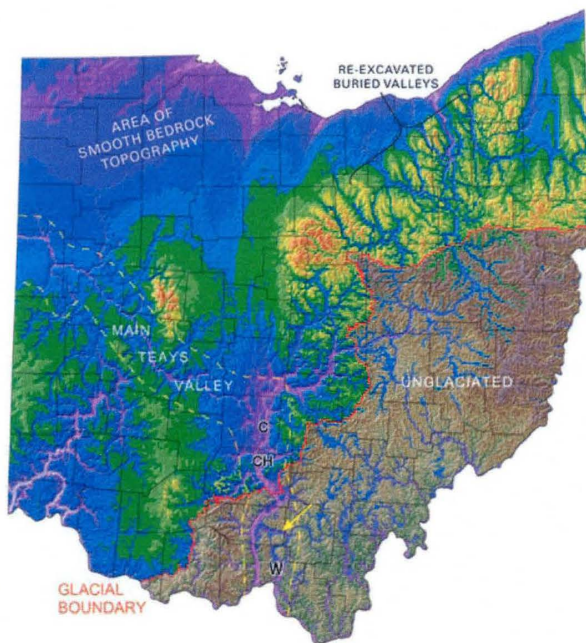


FIGURE 1.—Shaded bedrock-topography map of Ohio showing the sculpted bedrock surface that lies beneath glacial drift in northern and western Ohio and the land surface in unglaciated southeastern Ohio. Note the surface expression of the Teays Valley System south of the glacial boundary (arrow), the location of the main Teays Valley (between yellow dashed lines), the area of smooth bedrock topography, and the area of re-excavated preglacial bedrock valleys in northeastern Ohio. (W = Wheelersburg, C = Circleville, CH = Chillicothe) (modified from Ohio Division of Geological Survey, 2003).

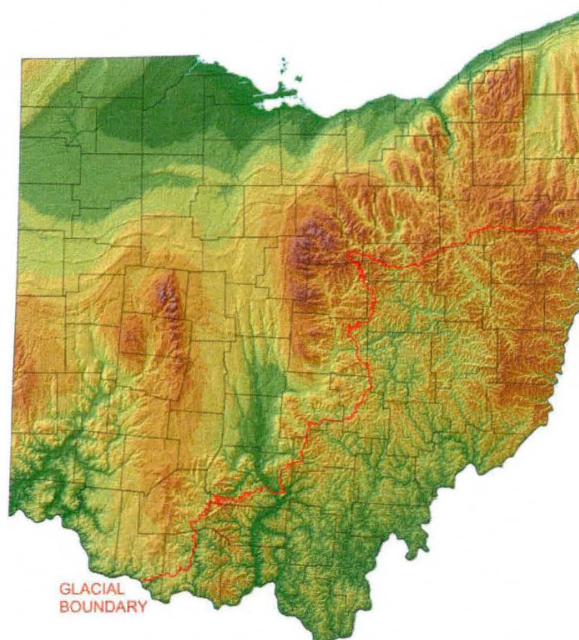
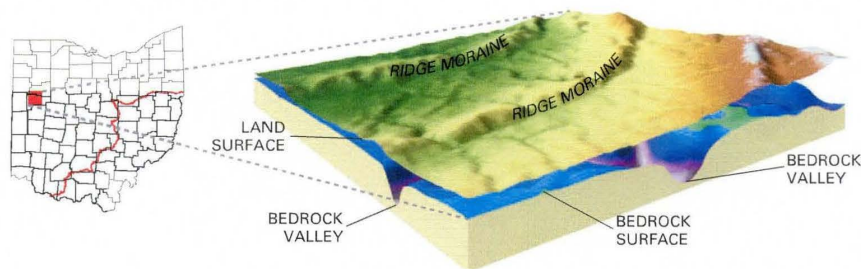


FIGURE 2.—Shaded elevation map of the land surface of Ohio with glacial boundary. Note the smooth landscape of glaciated northern and western Ohio compared to the high-relief landscape of unglaciated southeastern Ohio (modified from Powers, Laine, and Pavey, 2002).

FIGURE 3.—Schematic cross section of glacial drift overlying the bedrock surface. Note areas where drift thickness is controlled by thickening of glacial sediment over a relatively flat bedrock surface, by drift infilling bedrock valleys, or by fluctuations in both the land surface and the bedrock surface. Also note areas where valleys in the buried-bedrock surface are not evident on the land surface (illustration by Donovan M. Powers).



huge volumes of glacial meltwater away from the ice front and toward the Ohio River. In the process, many of these valleys were at times made deeper by the erosive force of fast-flowing meltwater streams, and at other times were partially filled with sediment. Some valleys in unglaciated Ohio contain thick deposits of clay and silt that accumulated on the bottoms of lakes that formed when glacial ice blocked the flow of rivers or when rapidly accumulating meltwater sediments blocked the mouths of smaller tributaries.

METHODS

Two digital data layers are required to generate the drift-thickness map: the surface-elevation layer and the bedrock-topography layer. Drift thickness is calculated by subtracting the bedrock-topography elevation from the land surface elevation. The bedrock-topography component is one of the products resulting from a multi-year effort by the ODNR, Division of Geological Survey to map the bedrock geology of Ohio. Bedrock-topography maps are required to determine the relief on the bedrock surface beneath thick layers of glacial drift. Bedrock-topography maps were created by the Division of Geological Survey for all 788 7½-minute topographic quadrangles in the state as part of a process to produce accurate bedrock-geology maps for glaciated portions of Ohio and for those areas beyond the glacial boundary where valleys are infilled with sediment. Data concentration and contour intervals on the original, hand-drawn bedrock-topography maps vary widely across the state in response to changing geologic and topographic conditions. These data consist mainly of water-well logs on file at the ODNR, Division of Water, supplemented by outcrop data, Ohio Department of Transportation bridge-boring data, and oil-and-gas-well data. During the course of mapping, over 162,000 data points were interpreted for bedrock-surface elevation and in some cases drift thickness. These points were plotted on maps and used as control for the bedrock-topography lines. Individual 24,000-scale bedrock-topography maps are available from the Division's Geologic Records Center.

Elevation contours and data points from the 788 bedrock-topography maps were digitized and compiled for the glaciated portions of the state and for the valleys beyond the glacial boundary containing significant accumulations of sediment deposited during and after glaciation. The bedrock-topography contours were digitally converted in an ArcGIS environment to create a continuous grid model (60 meter grid spacing). A statewide compilation map and digital dataset of the bedrock topography of Ohio (modified from Ohio Division of Geological Survey, 2003) are available from the Division of Geological Survey.

Uncolored areas of southeastern Ohio represent extensive portions of unglaciated Ohio where the land surface and the bedrock surface are essentially the same. On the original maps in these areas, bedrock-topography lines were restricted to the buried-valley portions of the map and were not drawn in upland portions.

The second component needed to create the drift-thickness map, the land-surface topography, is based largely on data derived from the U.S. Geological Survey's National Elevation Dataset (30 meter grid spacing). These data have been modified extensively by the Ohio Division of Geological Survey to replace some anomalous errors that are inherent in portions of the National Elevation Dataset. A statewide compilation map and digital dataset of the shaded elevation of Ohio (modified from Powers, Laine, and Pavey, 2002) are available from the Division of Geological Survey.

A grid of the digitized bedrock-topography contours was subtracted from a grid of the land-surface Digital Elevation Model to derive a third grid (60 meter grid spacing) representing the thickness of the drift. This grid surface was shaded from the northwest, slightly above the horizon, to produce the appearance of a three-dimensional surface.

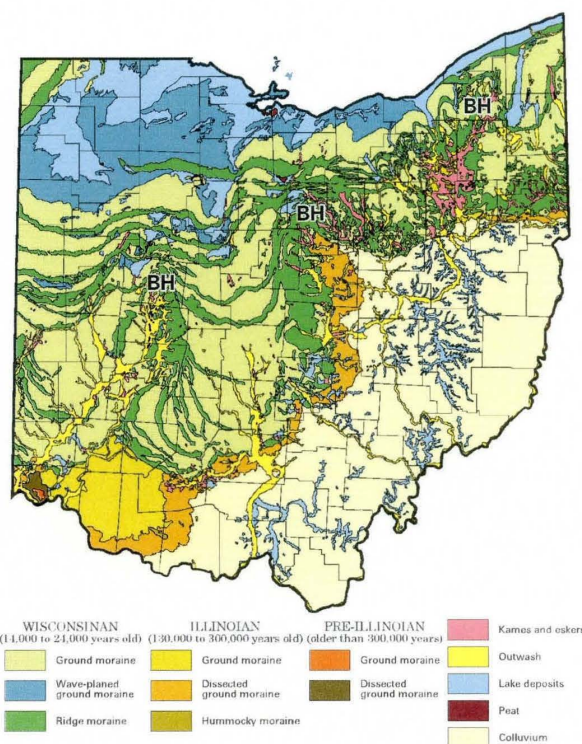
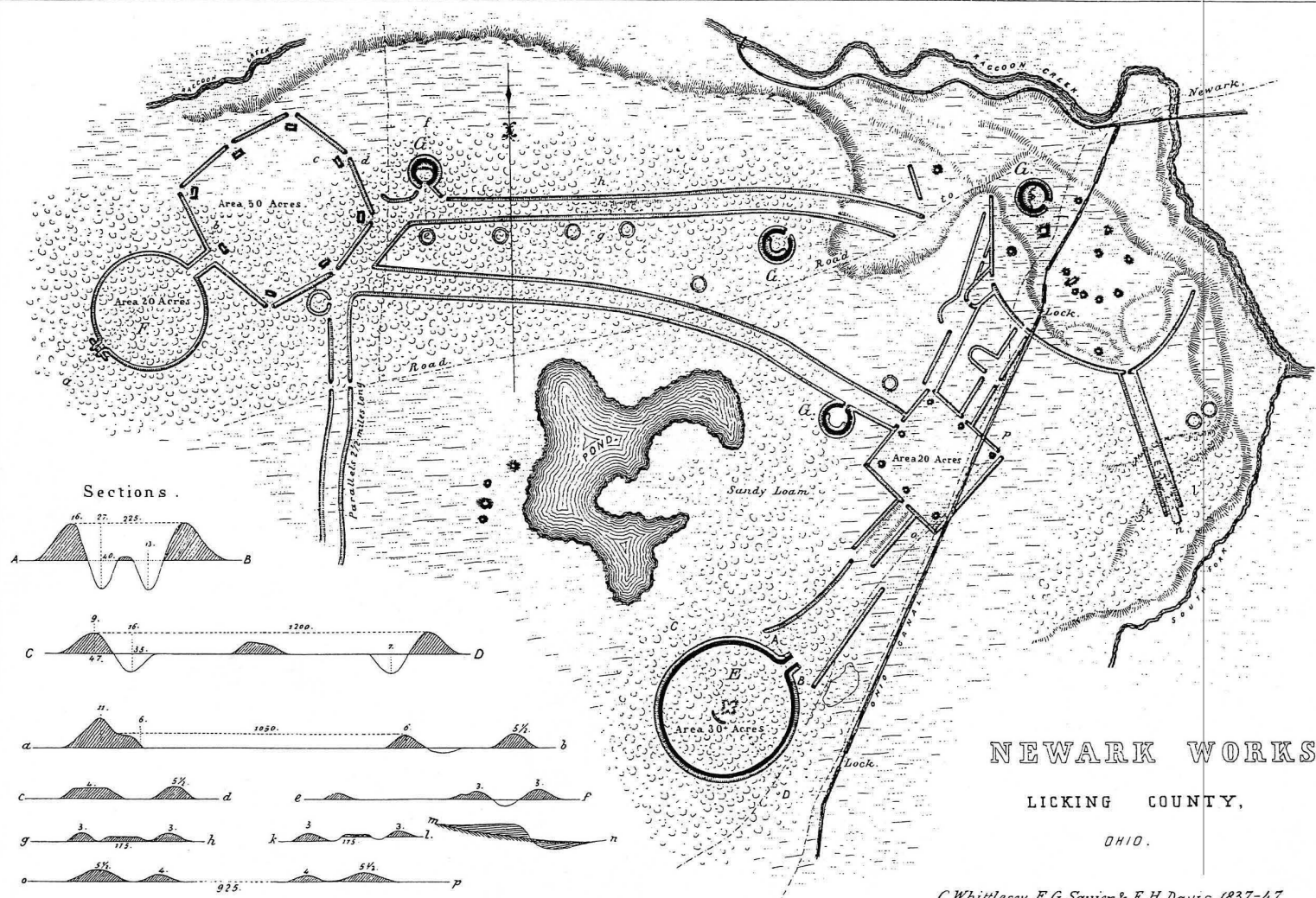


FIGURE 4.—Glacial map of Ohio showing the distribution of glacial sediments and their relative ages. Note glaciated northern and western Ohio, unglaciated southeastern Ohio, and the position of ridge moraines and the lake deposits and wave-planed ground moraine of the Lake Erie Basin. Bedrock highlands (BH) impeded the southward advance of glacial ice causing the moraines to form a lobate configuration (illustration by Lisa Van Doren; modified from Pavey and others, 1999).

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XXV.



ANCIENT MONUMENTS of the MISSISSIPPI VALLEY
 E. G. SQUIER A. M., and E. H. DAVIS, M. D. - 1848
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